THE SCHUMANN RAYS AS AN AGENT FOR THE STERILIZATION OF LIQUIDS

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(WITH ONE FIGURE)

The early investigators were unsuccessful in their attempts to use light as a sterilizing agent, partly because of a lack of knowledge concerning the nature of the action of ultra-violet light upon living organisms, and partly because of the inefficiency of the sources of light at their command.

Finsen and his co-workers greatly extended our knowledge of the action of ultra-violet light upon living organisms, and Kuch (6) in 1905 (working in the laboratories of the firm of W. C. Heraeus) invented the quartz mercury vapor arc, a source of light very rich in the ultra-violet rays.

Nogier and Thevenot (8) in 1908 were the first to make use of the quartz mercury vapor arc in the study of the biological action of light, and Courmont and Nogier (3) in 1909 advocated the use of the quartz mercury vapor arc for the commercial sterilization of potable waters. They found that water which was contaminated with *Bacillus coli* and *B. Eberth* was sterilized in 1–2 minutes by a quartz mercury vapor lamp 3 dm. in length, using 9 amperes of current. The water passed through an iron tube which inclosed the quartz lamp.

In the same year Henri and Stodel (5) claimed to have sterilized milk with a quartz mercury vapor lamp. They performed many experiments and were certain that the milk was sterilized and that there were no bad effects on the milk such as are produced in the sterilization of milk by heat.

Courmont and Nogier (2) pointed out the fact that ultra-violet light does not penetrate colloidal solutions, and Dornic and Daire (4), in a paper on the use of ultra-violet rays for sterilization in the brewing industries, pointed out that the light could not sufficiently penetrate milk or cream to sterilize them, and that, even if it did, the method would not be practical, because the ozone formed would be harmful to the milk and cream. They were not able to sterilize water completely by ultra-violet light, but they found that the number of bacteria was greatly reduced by the treatment.

BILLON-DAGUERRE (1), nephew of the inventor of the daguerreotype, described in 1909 a new quartz lamp for the sterilization of liquids. The source of light was a quartz discharge tube filled with rarefied hydrogen gas. Other gases were also used. Such a lamp, according to BILLON-DAGUERRE, emits Schumann rays. In a paper published in 1910 he figured an improved lamp and asserted that with this lamp water containing 29,000 bacteria (*Bacillus coli*) per cc. could be sterilized at the rate of 5 liters per minute. The discharge tube of the improved lamp was 25 cm. long and 20 mm. in internal diameter. It was excited by the current from the secondary of an induction coil which gave a spark 15 mm. in length; the primary of the induction coil was operated by a current of 2 amperes at 6 volts. He said that the lamp was more than 20 times as efficient as the mercury vapor arc.

URBAM, SCAL, and FEIGE (9) questioned the efficiency of Schumann rays for sterilizing, because of their small penetrating power. They recommended a lamp with terminals of carbon and of aluminum for sterilizing large quantities of water.

LYMAN (7) studied the absorption by water of the Schumann rays and showed that light of wave-length 1750 Ångström units was completely absorbed by a layer of water 0.5 mm. thick. He pointed out the improbability of the results claimed by BILLON-DAGUERRE.

The Schumann rays are undoubtedly very active chemically, but they have such a small penetrating power that it seemed improbable to Professor LYMAN (at whose suggestion the writer undertook this work) that in a sterilizer such as described by BILLON-DAGUERRE the bacteria would be exposed to sufficient light to kill them. BILLON-DAGUERRE passed the water, which he was attempting to sterilize, through his apparatus at so rapid a rate that sufficient exposure for sterilization seems impossible, since the organisms in the water could be affected by the rays only during the times when they were in very close proximity to the discharge tube.

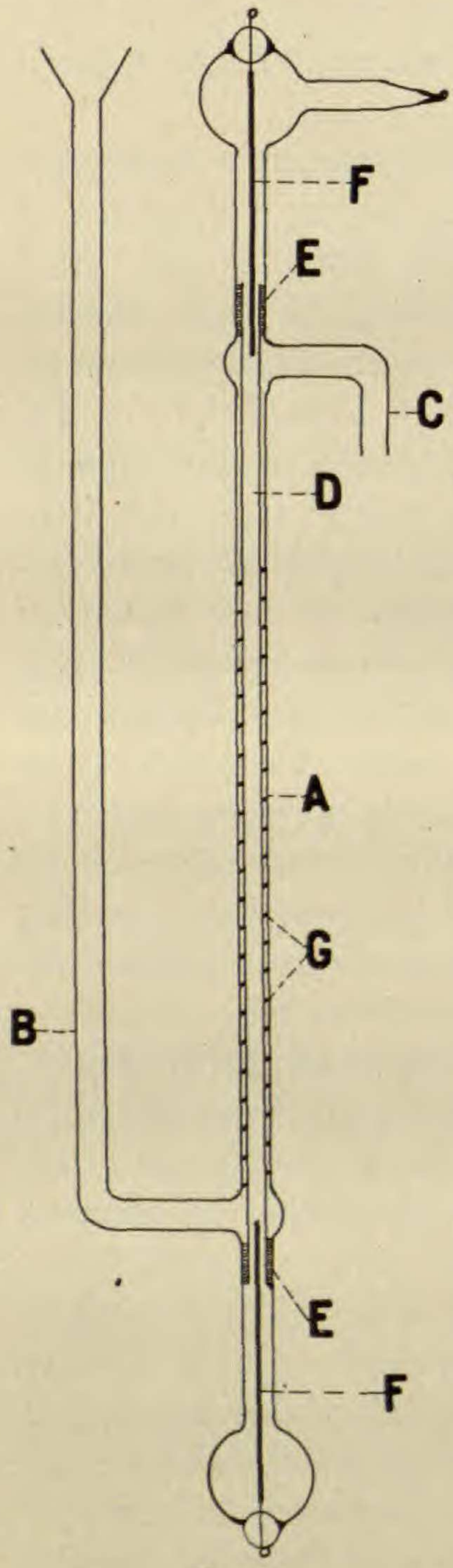

FIG. 1

In order to test the efficiency of BILLON-DAGUERRE'S method, a sterilizer similar to the one which he described was constructed by the writer, and distilled water, contaminated with various bacteria, was passed through it. Although the water passed through at a much slower rate than the one given by BILLON-DAGUERRE, the water was not sterilized. Another sterilizer was then constructed in which the organisms could receive a much longer exposure; the discharge tube was longer, the volume of liquid exposed at any one time was much less, and the chance of the bacteria coming in close contact with the discharge tube was much greater, as the liquid was caused to circulate around the discharge tube. The construction of the improved sterilizer is shown in fig. 1. A glass tube *A* with bulbs on each end, into which electrodes *F* were sealed, had side tubes as shown at *B* and *C*. The electrodes were of aluminum. The tube *B* served as the inlet and *C* as the outlet for the liquid under treatment. Within the glass tube there was a very thin-walled tube of quartz (*D*). The distance between the outside of the quartz tube and the inside of the glass tube was 0.3 mm. The quartz tube was sealed to the glass tube at *E*, *E* with DeKotinski cement, so that the space between the two tubes was not in communication with the remainder of the interior of the glass tube. A gold wire was drawn down exactly to fit this space. The wire was coiled spirally around the quartz tube as shown at *G*. The distance between the inlet tube *B* and the outlet tube *C* was 16 cm. The quartz tube was 5 mm. in outside diameter, and the gold wire made 15 turns about the quartz tube. The solution under treatment was thus spread into a thin layer, 0.3 mm. in thickness, and took a spiral course through the sterilizer. The discharge tube was filled with rarefied unwashed hydrogen, containing carbon dioxide as an impurity, since a discharge tube filled with pure hydrogen would not emit light of wave-lengths between 2000 and 1675 Ångström units. The carbon dioxide which the tube contained filled in this gap. This is important, for it is highly improbable that the strong 1600 lines of the hydrogen spectrum, because of their small penetrating power, could be effective in sterilizing the water. Any virtue which the sterilizer might have must be due to its emitting light between wave-lengths in 1850 and 1675 Ångström units.

A discharge tube filled with carbon dioxide is short-lived. After the tube has been excited a few hours, the carbon dioxide disappears and is replaced by hydrogen. To insure a carbon dioxide spectrum, the discharge tube was filled and pumped before each experiment.

The discharge tube was excited by a current of 14 milliamperes, and Cambridge city water was passed through the sterilizer at the rate of 10 cc. per minute. By this treatment the bacterial count of the water was reduced from 50 to 4 per cc., and the fungal count from 3 to 1 per cc. In none of the experiments was the water completely sterilized.

It is apparent that a hydrogen discharge tube such as is described by BILLON-DAGUERRE is not an efficient source of light for photo-sterilization.

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